Searches for electroweakly produced supersymmetry with CMS

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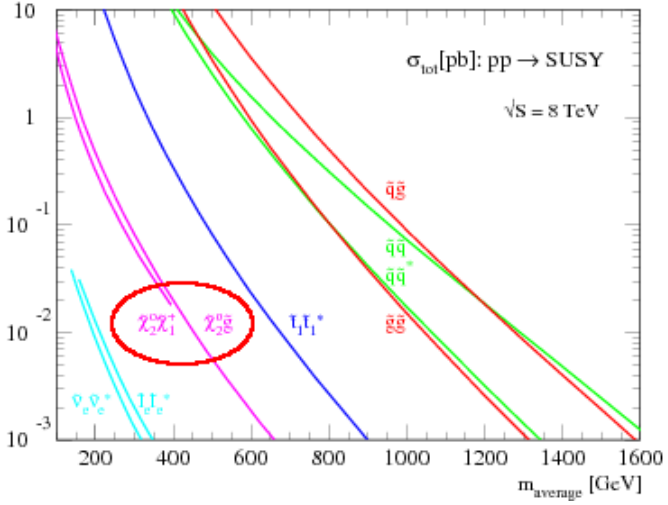
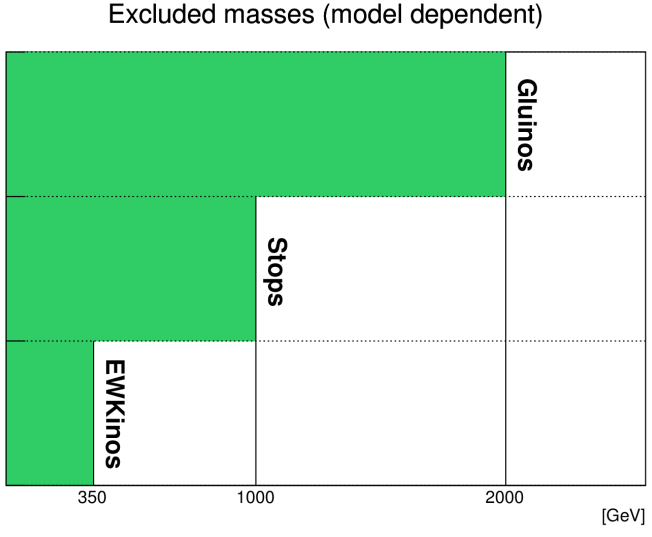
The Case for electroweak SUSY

- Classic naturalness arguments require light gluinos, stops, higgsinos
- Gluinos and stops with largest cross section, strong exclusion exist





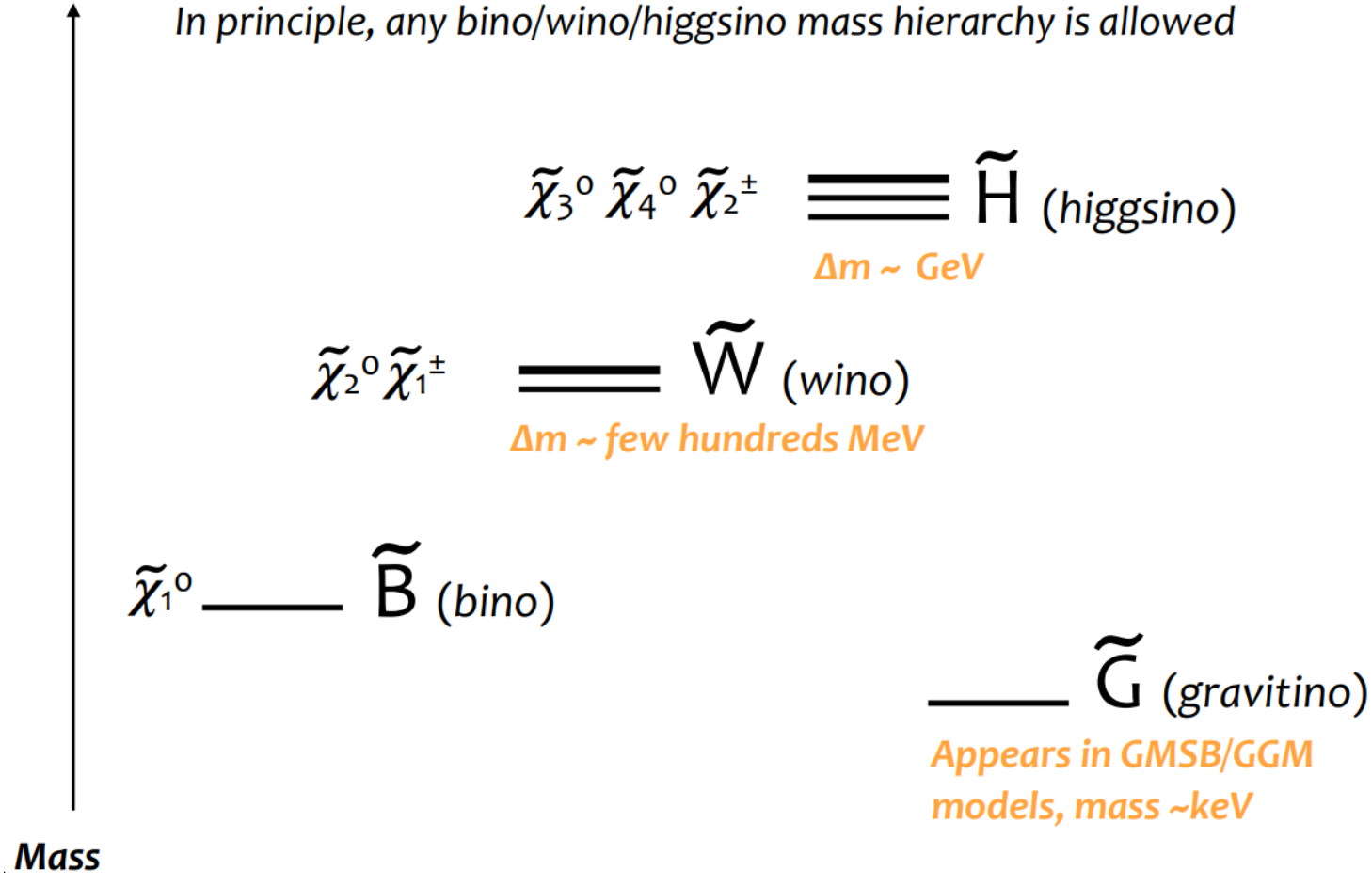
Only higgsinos enter higgs mass at tree level

tree-level:

$$-\frac{m_Z^2}{2} = |\mu^2| + m_{H_u}^2 + \mathcal{O}\left(\frac{1}{\tan^2\beta}\right)$$

→ Electroweak SUSY dominant process at LHC?

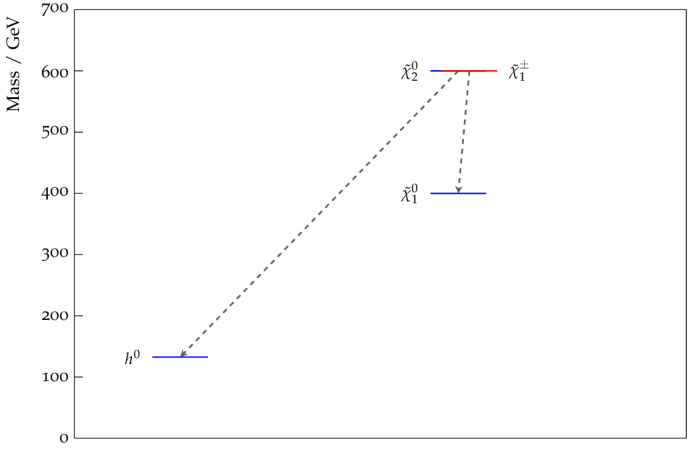
Electroweak Mass Parameters



Electroweak Mass Hierarchy

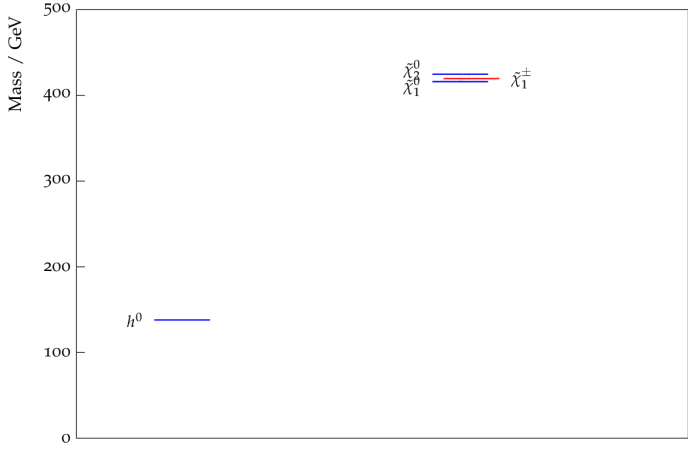
Mostly two mass hierarchies considered

$$\tilde{B} < \tilde{W} \ll \tilde{H}$$



- Bino-like LSP and Wino-like NLSP
- Mass difference can be large $\rightarrow$ heavy objects
- Associated $\tilde{\chi}_2^0\tilde{\chi}_1^\pm$ with highest SUSY EWK cross section

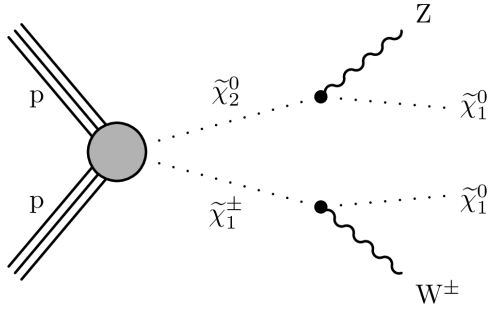
$$\tilde{H} \ll \tilde{B} < \tilde{W}$$



- Natural (higgsino mass $\lesssim$ 400 GeV)
- Compressed mass spectrum, leading to low E_T^{miss}, soft decay products
- Smaller cross section

Electroweak Signatures

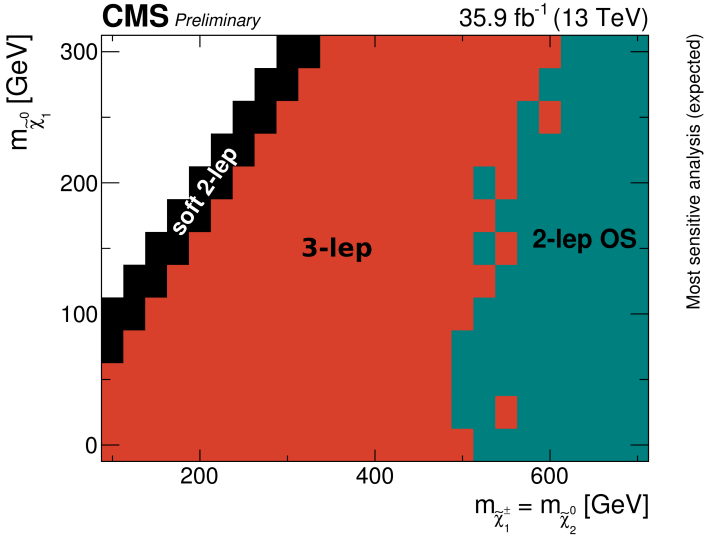
- Searches optimized on Simplified Models
- Decay to leptons, vector bosons, higgses
- Clean experimental signatures
- Hadronic activity only due to bosonic decay products or initial state radiation
- 2d scan in sparticle masses



Signatures considered in this talk:

- $WZ : 2\ell$ + jets + E_T^{miss}
- $WZ : 2$ soft ℓ + E_T^{miss}
- $WZ : 3\ell + E_T^{\text{miss}}$
- $Wh : 1\ell + bb + E_T^{\text{miss}}$
- $hh : 4b + E_T^{\text{miss}}$

All searches in this talk use 35.9 fb^{-1} of p-p collisions at $\sqrt{s} = 13$ TeV

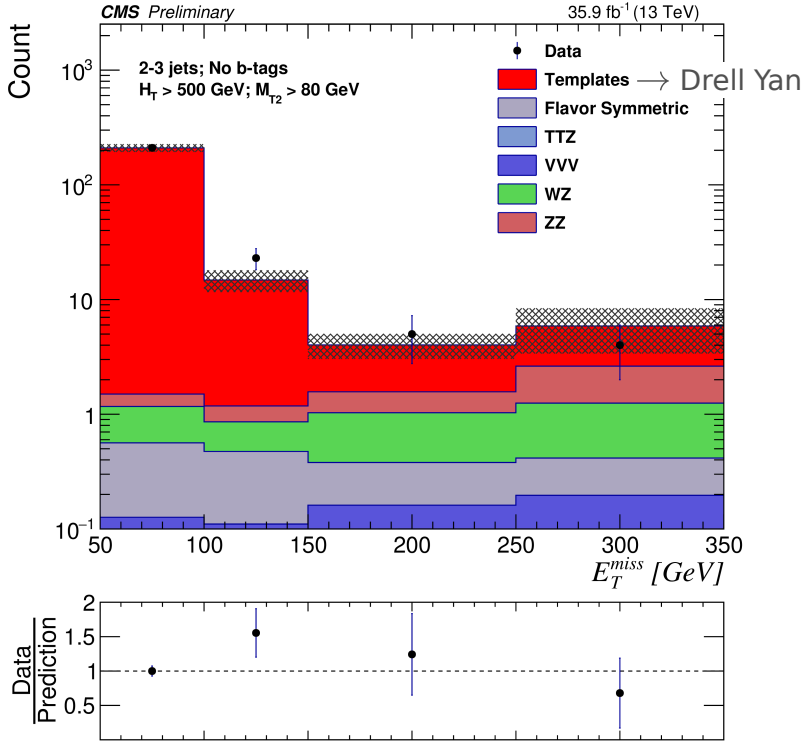


General CMS Search Strategy

Example: Same Flavor Opposite Sign Lepton Search

Background modeling:

- Measure backgrounds in background enriched regions
- Dominating backgrounds measured fully data-driven, smaller background semi data-driven
- Rare background taken from MC, validated in dedicated regions

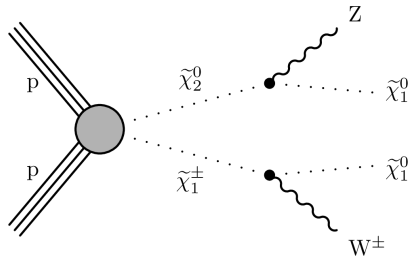


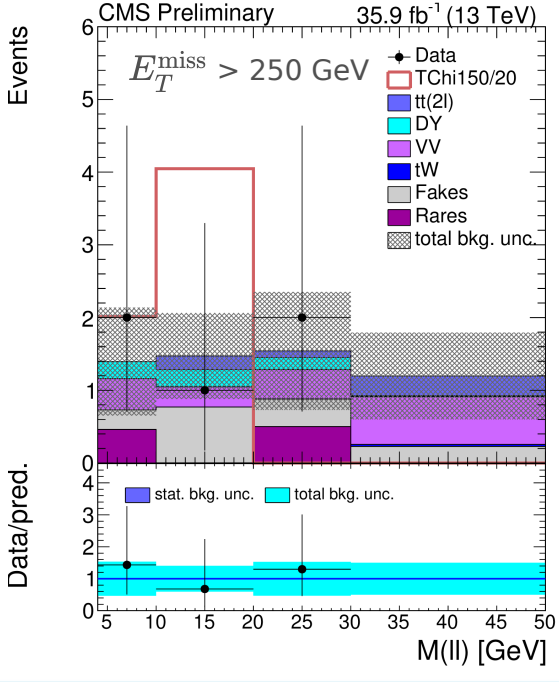
Signal regions:

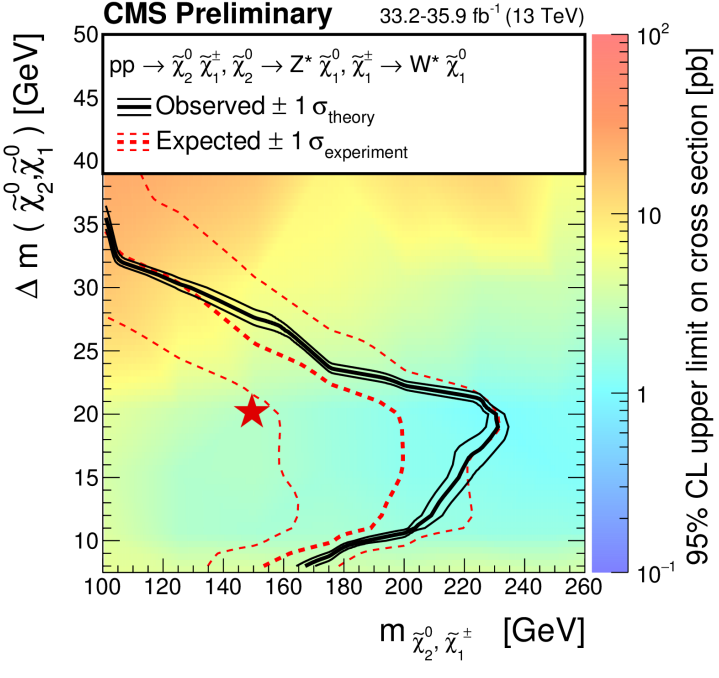
- Pick observables that discriminate signal events from background (e.g. E_T^{miss}, invariant mass of lepton pair (to mimic Z mass), ...)
- Bin in these observables; generic approach

Soft Opposite Sign Lepton Search

- Target compressed scenarios
- Events need to recoil against initial state radiation jet to pass trigger requirements
- 5 GeV < lepton p_T < 30 GeV
- Dominated by diboson and "fake" lepton background

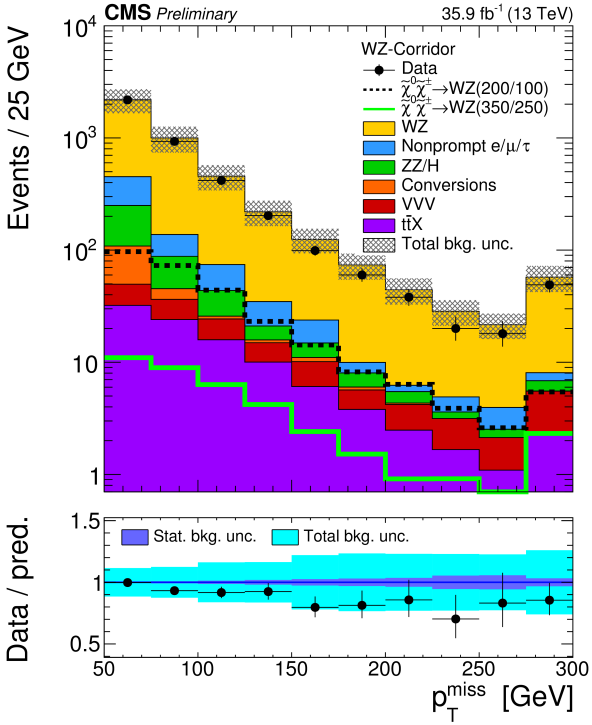


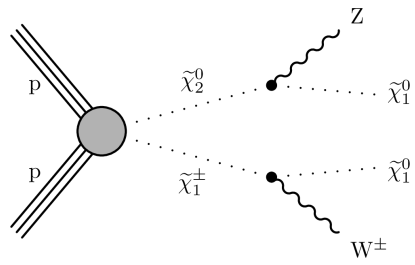


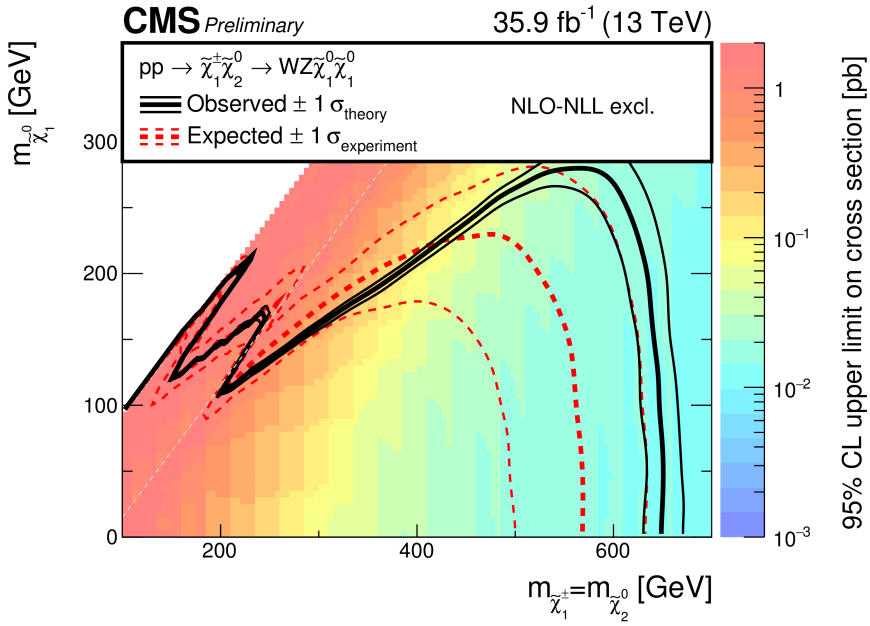


Multilepton Search & EWKino Combination

- Dominated by WZ
- Signal looks background-like in "corridor" region





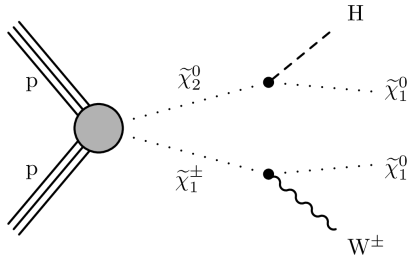


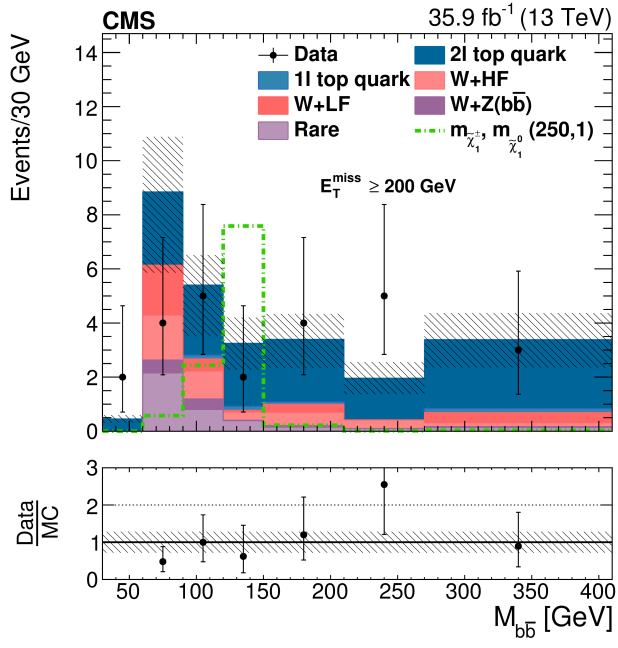
Fermilab

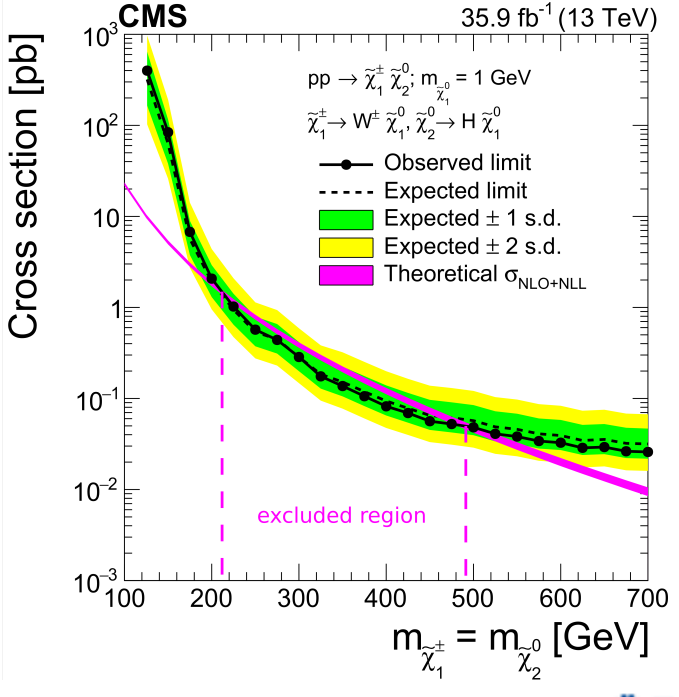
1lbb Search

- Dominated by ttbar
- Use transverse mass to suppress background:

$$M_T = \sqrt{2p_T^{\ell} E_T^{\text{miss}} (1 - \cos\Delta\phi)}$$



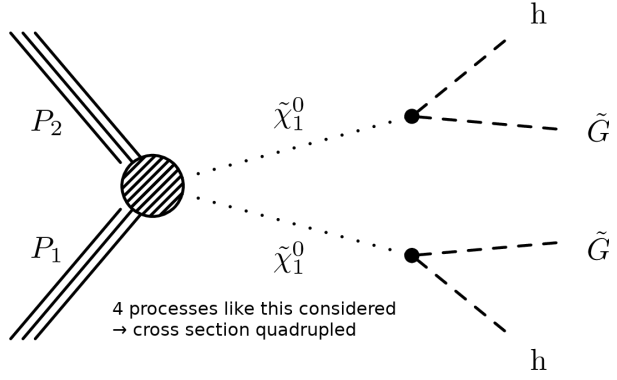


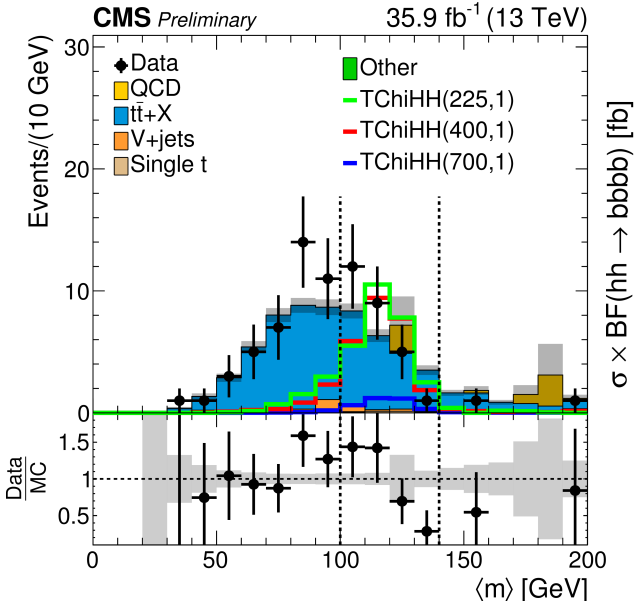


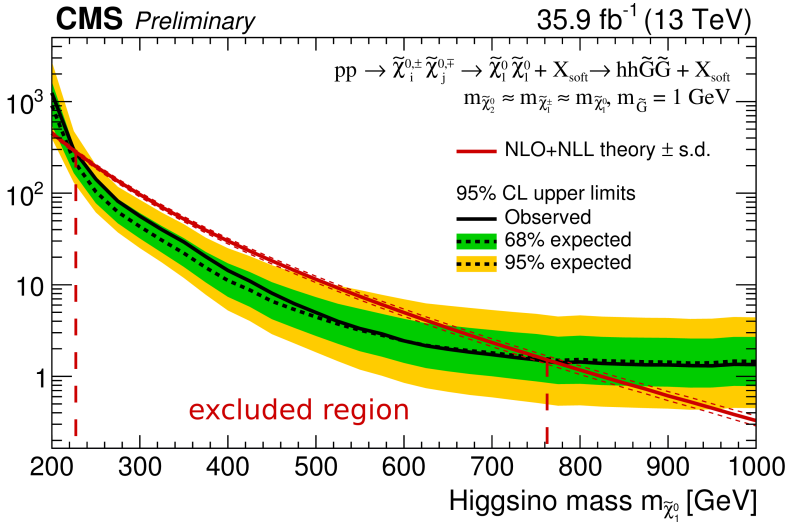
Fermilab

GMSB Higgsinos in 4b Search

- Consider higgsino production with decay to gravitino (GMSB)
- 3b and 4b final states considered
- Use average mass of two higgses $\langle m \rangle$ as discriminator







Conclusions

- As part of extensive search program in CMS, showed a glimpse of the Electroweak SUSY effort
- Searches optimized in different models, motivated by naturalness
- Observation and expectation within statistical uncertainties

- Limits in $\tilde{\chi}_2^0\tilde{\chi}_1^\pm \rightarrow WZ\tilde{\chi}_1^0\tilde{\chi}_1^0$ model extended up to $\tilde{\chi}_2^0$ = 650 GeV for massless LSP and $\tilde{\chi}_2^0$ = 230 GeV for compressed scenarios
- In $\tilde{\chi}_2^0\tilde{\chi}_1^\pm \rightarrow Wh\tilde{\chi}_1^0\tilde{\chi}_1^0$, masses between 220 GeV and 490 GeV excluded
- Higgsinos with mass in the range 225 to 770 GeV excluded in GMSB model

- New ideas and final states are continuously added!
- There are many corners that are still to be explored!

References

- "Same Flavor Opposite Sign Lepton Search": Search for new physics in final states with two opposite-sign, same-flavor leptons, jets, and missing transverse momentum in pp collisions at $\sqrt{s}$ = 13 TeV
  (CMS-PAS-SUS-16-034)
  https://cds.cern.ch/record/2257293
- "Soft Opposite Sign Lepton Search": Search for electroweak production of charginos and neutralinos in multilepton final states in pp collision data at $\sqrt{s}$ = 13 TeV
  (CMS-PAS-SUS-16-048)
  https://cds.cern.ch/record/2256640
- "Multilepton Search": Search for electroweak production of charginos and neutralinos in multilepton final states in pp collision data at $\sqrt{s}$ = 13 TeV
  (CMS-PAS-SUS-16-039)
  https://cds.cern.ch/record/2256434
- "EWKino Combination": Combined search for electroweak production of charginos and neutralinos in pp collisions at $\sqrt{s}$ = 13 TeV
  (CMS-PAS-SUS-17-004)
  https://cds.cern.ch/record/2273907
- "1lbb Search": Search for electroweak production of charginos and neutralinos in WH events in proton-proton collisions at $\sqrt{s}$ = 13 TeV
  (arXiv:1706.09933 [hep-ex])
  https://arxiv.org/abs/1706.09933
- "GMSB Higgsinos in 4b Search": "Search for the pair production of Higgsinos in pp collisions at $\sqrt{s}$ = 13 TeV in final states with Higgs bosons and large missing transverse momentum"
  (CMS-PAS-SUS-16-044)
  https://cds.cern.ch/record/2256648